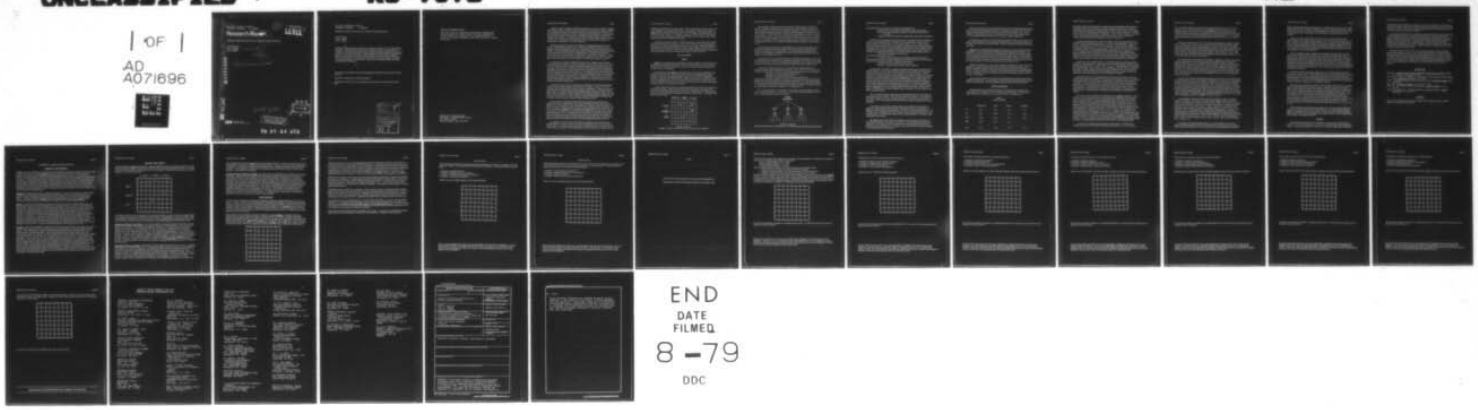
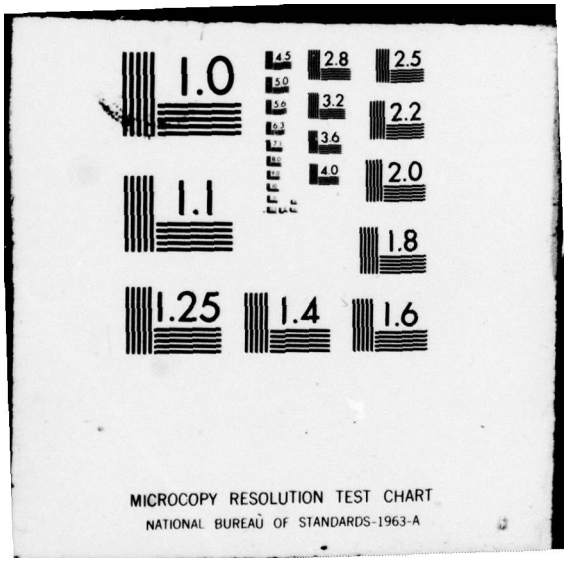
AD-A071 696 IBM THOMAS J WATSON RESEARCH CENTER YORKTOWN HEIGHTS N Y F/G 5/10
ASPECTS OF SOLUTION STRUCTURE IN DESIGN PROBLEM SOLVING.(U)
APR 78 J M CARROLL, J C THOMAS, L A MILLER N00014-72-C-0419
UNCLASSIFIED RC-7078 NL

1 OF 1
AD A071696



END
DATE FILMED
8-79
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
7.1
8.0
9.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(14) RC-7078 (#30334) 4/20/78
Computer Science 24 pages

(2)

LEVEL II

(9) Research Report.

(6) Aspects of Solution Structure in Design Problem Solving.

(10) John M. Carroll,
John C. Thomas
Lance A. Miller

(11) 24 Apr 78

(12) 32p.

(15) N0014-72-C-0419

AD A071696

DDC FILE COPY

349 250

DDC
RECEIVED
JUL 25 1979
A

IBM Research Division
San Jose · Yorktown · Zurich

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

79 07 24 079

RC 7078 (#30334) 4/20/78
Computer Science 24 pages

Aspects of Solution Structure in Design Problem Solving

John M. Carroll
John C. Thomas
Lance A. Miller

ABSTRACT: Forty-eight subjects reiteratively designed a schedule for a set of abstract library procedures. Obtained solution schedules were measured in terms of (1) solution time, (2) satisfaction of functional design requirements, (3) stability of solution through the sequence of iterations, and (4) cluster, the degree to which solutions reflected the inherent structure of the problem. It was found that the extent to which schedules were clustered was a significant predictor of satisfaction of functional design requirements, and that the stability of solutions was a significant predictor of solution time. Weak effects of problem statement on solution variables were also identified.

This research was supported in part by the Engineering Psychology Programs, Office of Naval Research.

Approved for public release, distribution unlimited.

Reproduction in whole or in part is permitted for any purpose of the United States Government.

Accession For
NTIS GRA&I
DDC TAB
Unannounced
Justification
By
Distribution/
Availability Codes
Dist. | Avail and/or special
A

LIMITED DISTRIBUTION NOTICE

This report has been submitted for publication elsewhere and has been issued as a Research Report for early dissemination of its contents. As a courtesy to the intended publisher, it should not be widely distributed until after the date of outside publication.

Copies may be requested from:
IBM Thomas J. Watson Research Center
Post Office Box 218
Yorktown Heights, New York 10598

Problems, problem statements, and problem solutions have at least one thing in common: they all have structure. A problem consists of a particular set of givens and goals; a statement of the problem presents this set of givens and goals in a particular manner; a solution of the problem presents a particular set of moves or conclusions which begin with the givens and are directed towards the goals. The structure of problems, problem statements, and problem solutions is not arbitrary. In limiting cases, we know that certain problem solutions will not be successful, that certain problems are unsolvable, and that certain problem statements are ungrammatical, contradictory, or otherwise incoherent.

However, the structures of these three aspects of a problem-solving situation are not always so trivially related. Quite often, for example, the problem statement of a puzzle problem is intentionally designed in such a way to obscure a key fact or deduction about the problem. Thus, two problem statements may contain the same denotative information but may not be equivalent from the viewpoint of problem solution. They may contain identical elements, but structure these elements very differently. Analogously, two problem solutions may contain many of the same moves and the same conclusions, but they still may ultimately differ in how successfully they treat the problem. The ordering of the moves is critical.

One question that emerges immediately from this train of thought is how these three aspects of structure are related. Can they be identical, must they be (in order for the solution to be successful)? Must they stand in some particular relation in order that the solution be successful, or in order that it be optimal? Characteristically, studies of problem solving have confounded problem structure and problem statement, manipulating these two simultaneously and looking for differences in problem solution. In the study of problem isomorphs (Carroll, Thomas, & Malhotra, 1978; Simon & Hayes, 1976), investigators have tried to unconfound the structure of the problem and the structure of its statement. Problem structure is maintained while problem statement is varied across some dimension (e.g., time/space in Carroll et al., transfer/change in Simon & Hayes). Obtained differences in structure of solution can then be attributed to problem statement alone.

The present study is directed at this same set of questions. We are concerned with the relation between problem statement and the structure of solutions. However, we wish to extend the current notions of both of these variables. Traditionally, of course, the structure of problem solution is operationally assessed by measurements of success, and occasionally by solution time. In the present study, we add two further indices of problem solution. The first, cluster, indicates the degree to which the structure of the problem solution is isomorphic to the structure of the problem. The second, stability, indicates how ballistically the problem solver converges on the final solution during later stages of problem solution.

Recent studies of isomorphic problem statements have often manipulated problem statement by simply exchanging content words in a well-defined, relatively simple, puzzle-problem (e.g., Simon & Hayes, 1976). We manipulate the variable of problem statement by altering the order in which the problem solver encounters information about the problem. We focus on a relatively ill-defined type of problem called design (Reitman, 1965; Simon, 1973). Our choices are motivated by our overall theoretical concerns with complexity and ecological validity (Brunswik, 1956). It is well-known that experimental work on human thinking and problem solving rarely confronts situations of more than trivial complexity. One might say that only in psychological studies of problem solving are there unique solutions derivable by a small finite number of well-defined moves. Real world thinking generally isn't like this.

For example, it is common in the real-world to be presented with a problem that has several solutions, the best of which has to be selected on grounds of style, or extra-problem considerations. It is common to be presented with a problem piecemeal; to find that you need to do X, later that you need to do Y, and much later that you need to do Z. Almost never are

problems presented all at once on index cards. In our research we have tried to capture some of the properties of real-world problem solving. The problem we address in this paper is a design problem, stemming from other interests in software design. The problem has not one but many "correct" solutions. It is complex; involving 24 entities defined on 3 dimensions. We present problem information piecemeal and ask subjects at every stage to offer a partial solution based on what they know to that point.

The present study also constitutes a further exploration of our particular type of design problem, first presented in Carroll et al. (1978). In the earlier study, we assessed solution structure only in terms of a performance score and time to solution. Indeed, the problem was quite difficult, and performance rather poor; further measures might have been difficult to interpret. In the present study, we have refined the problem somewhat hoping to obtain better overall performance, and then to examine other details of solution structure.

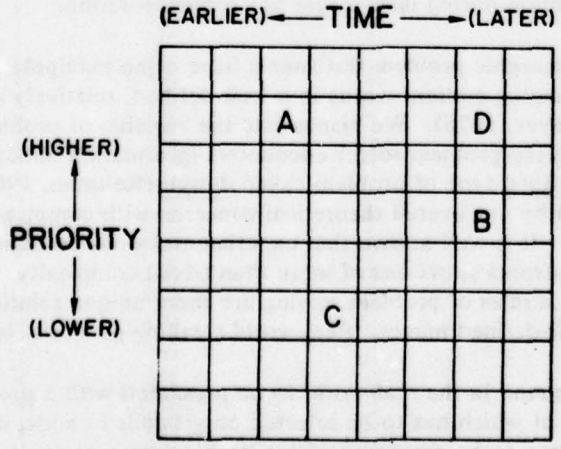
THE EXPERIMENT

Method

Materials. The materials for the experiment consisted of booklets. The first four pages of the booklet contained general instructions. The instructions explained that in developing a schedule for a set of library procedures, several sorts of possible interrelations between the procedures had to be considered.

A given procedure can facilitate another procedure, in the sense that cataloging a book facilitates shelving the book. A given procedure can have greater priority than another procedure, in the sense that signing out books to borrowers seems to be a higher priority procedure than tidying up the Reading Room. Finally, two procedures may employ the same or different resources, in the sense that moving old books to archival storage and retrieving books that have been requested from archival storage employ the same resources (both require someone to make a trip to the library's archives).

A matrix representation scheme was introduced and illustrated: The matrix consisted of an 8 X 8 block of squares. Squares to the left were earlier than squares to the right. And squares above have higher priority than squares below. Finally, squares in a common column can share resources effectively, while squares in different columns cannot. An example of the matrix is given in Figure 1.



Caption for Figure 1:
Example of matrix representation that subjects used in the experiment.

The instructions explained that when one procedure facilitates another procedure, it should be scheduled in the matrix before that procedure. Thus, in Figure 1 procedure C facilitates procedures D and B, and is facilitated by procedure A. When one procedure has higher priority than another procedure, it should be scheduled higher in the matrix than the other procedure. Thus, procedure B has higher priority than procedure C, but lower priority than procedures A and D. And, when one procedure employs the same resources as another procedure, it should be scheduled in the same column of the matrix as that other procedure. In Figure 1, procedures D and B employ the same resources. Conversely, if two procedures employ different resources, they should be scheduled in different columns (e.g., procedures A and C).

Certain pairs of these relations are independent (e.g., a procedure can facilitate or be facilitated by another procedure, and still have either higher or lower priority than that procedure). Other pairs are non-independent (e.g., if two procedures employ the same resources and accordingly are scheduled in the same column of the matrix, then neither can facilitate or be facilitated by the other).

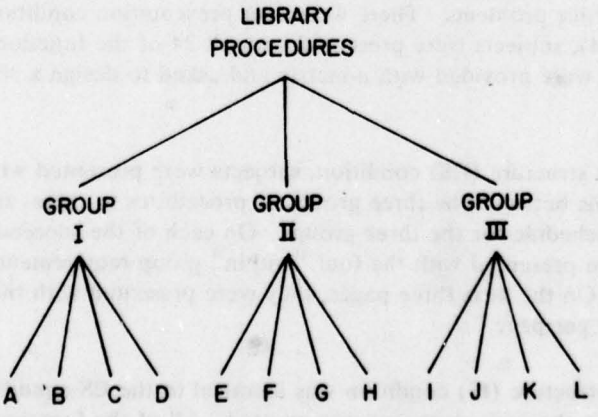
Pages five and six of the booklet consisted of two simple practice problems. Each of the practice problems was comprised of four functional requirements, bottom-level goals, relating four library procedures. The practice problems were intended to test the subjects' understanding of the various relations, like priority, and their mastery of the matrix representation.

A total of 24 functional requirements for the main library schedule problem were contrived, relating 12 hypothetical library procedures: A, B, C, D, E, F, G, H, I, J, K, and L. Examples are given below. (The text of the ES condition booklet appears as the Appendix.)

Procedure A is lower in priority than procedure J.
Procedure H is facilitated by procedure F.
Procedure L employs different resources than procedure D.

Each of the 24 functional requirements related two of the 12 procedures and each procedure appeared four times as the argument in a functional requirement. The 24 functional requirements were also equally distributed among the three types of relations: eight involved priority (4 "higher than", 4 "lower than"), eight involved resources (4 "same as", 4 "different than"), and eight involved facilitation (4 "facilitates", 4 "is facilitated by").

The 12 library procedures were divided into three groups: Group I consisted of A,B, C, and D; Group II consisted of procedures E, F, G, and H; and Group III consisted of I, J, K, and L. This organization is indicated in Figure 2.



Caption for Figure 2:
Presumed problem structure: organization of 12 schematic library procedures into three groups.

These three groups were defined to be related in the following ways:

In general, Group I procedures are facilitated by Group II procedures.
In general, Group II procedures employ the same resources as Group III procedures.
In general, Group III procedures have higher priority than Group I procedures.

The 24 functional requirements comprising the library scheduling problem consisted of 12 "within" groups requirements and 12 "between" groups requirements. Each of these two subsets contained an equal number of all the possible relations. The 12 "within" groups requirements related members of the three groups, 4 requirements related members of each of the groups. The 12 "between" groups requirements further divided into six requirements that followed directly from the three general relations between groups, and six that did not. An example of a requirement that follows from the general between group relations would be,

"Procedure B is facilitated by procedure E."

This follows directly from the fact that,

"In general, Group I procedures are facilitated by Group II procedures."

The remaining six "between" group requirements did not follow directly from these relations, but were never inconsistent with them. Examples are given below.

Procedure E is lower in priority than procedure K.
Procedure L employs different resources than procedure D.

By chance alone, fewer than 12 requirements should be within groups, and more than 12 should be between. That is, if pairs of library procedures were randomly selected and then assigned some relation, fewer than 12 would be within, more than 12 between. Within a group, of the possible 6 pairings of the four members, 4 are actually realized by the functional requirements of the design problem. However, between groups, of the possible 48 pairings, only 12 are related by functional requirements in the statement of the design problem. In summary, just in terms of the number of functional requirements relating the various procedures, the procedures within the same group are more related than procedures in different groups. Thus, the distribution of functional requirements vis-a-vis within and between group relations inherently biases for the grouping structure of library procedures as illustrated in Figure 2. On this basis, we take the grouping structure of Figure 2 to be the structure of the library scheduling problem.

The main scheduling problem appeared in the booklet imediately after the introductory pages and the practice problems. There were four presentation conditions. In the simultaneous condition (SIM), subjects were presented with all 24 of the functional requirements on a single page. They were provided with a matrix and asked to design a schedule for the library procedures.

In the explicit structure (ES) condition, subjects were presented with a page that explained the relations between the three groups of procedures to them, and asked them to design an overall schedule for the three groups. On each of the succeeding three pages of their booklets, they were presented with the four "within" group requirements pertaining to one of the three groups. On the next three pages, they were presented with the 12 "between" group requirements, four per page.

The implicit structure (IS) condition was identical to the ES condition except that the initial page defining the various groups was omitted. All of the functional requirements were presented to the IS subjects in exactly the same order, but their booklets did not include a description of the grouping of the 12 procedures. Thus, they did not have advance knowledge of the group structure of the procedures.

The fourth condition is the non-structured (NS) condition. In this condition subjects were presented with the 24 functional requirements over 6 pages in their booklets, but the requirements were jumbled with respect to the group structure of the procedures. Thus, the NS condition is a scrambled IS condition: each page consisted of two "within" groups requirements (pertaining to different groups) and two "between" groups requirements.

Following the presentation of all 24 functional requirements, there was a final page of the booklet which presented no new information and which asked for a final solution (page 14 in ES, page 13 in IS and NS, and page 8 in SIM). The last two pages of the booklet contained a questionaire.

Procedure. The 48 undergraduate subjects, who were run in groups, were paid for their participation. First, the subjects read through the introductory pages of the booklet. Next, subjects were invited to ask questions of the experimenter. When all of the subjects understood the instructions, they were asked to work the first practice problem. The experimenter scored the solutions and then asked for and answered any further questions. This procedure was repeated for the second practice problem, after which subjects were permitted to procede with the main problem. The entire instruction period took about one hour.

Subjects were permitted to work on only one page of their booklet at a time. They were allowed to turn back to previous work, and to consult the instructions, but they were not allowed to change any of their previous work and they were not allowed to look ahead in the booklet. They were told that for the purposes of the experiment, their intermediate solutions were just as important as their final solutions, and they were encouraged to work carefully at all stages of the problem.

After working through the entire booklet and completing the final solution, the subjects signaled the experimenter. The experimenter recorded the time elapsed and asked the subject to fill out a questionnaire. The entire problem session took about one and a half hours.

Results and Discussion

Subjects' behavior was measured in four ways: Performance Scores, Solution Time, Clustering Ratio, and Instability. These four measures are defined below. We discuss the results obtained with each measure in turn. Refer to Table 1 for summary data.

Table 1
Summary Results:

	Performance	Time	Cluster	Instability
ES	23.5	43.5	.52	9.7
IS	23.2	38.2	.66	18.7
NS	23.4	43.4	.74	24.8
SIM	23.0	45.2	.68	
ALL	23.3	42.6	.65	17.5

We employ confidence intervals, simple correlation, and multiple regression (MR) analyses in assessing the results of the experiment. The MR analysis has the following seven variates: performance scores, solution time, clustering ratio, instability, explicit structure (ES), implicit structure (IS), and simultaneous presentation (SIM). (The latter three variates are "dummies" used to represent the four presentation conditions, see Cohen, 1968, for discussion.) Four MR analyses were performed taking each of the first four variates in turn as the dependent variable, and the remaining six as independent variables (or predictors).

A subject's performance score is simply the number of functional requirements, out of a possible 24, that his design solution satisfies. It is clear just from inspection of Table 1 that there is a ceiling effect on performance in this experiment. Indeed, the 95% confidence interval for performance is $22.7 < x < 23.8$. In multiple regression analysis, performance, as the dependent variate, obtains a coefficient of $R^2 = .45$, $F\ (6, 39) = 5.31$, $p < .001$. However, of the six predictors, only clustering contributes significantly to this correlation (i.e., obtains a significant partial correlation), $t\ (45) = 4.19$, $p < .001$. Clustering (as defined below) is an index of how well a subject's final solution reflects the inherent structure of the problem (i.e., as sketched in Figure 2). This result indicates that the more a solution accords with the inherent structure of the problem, the more functional requirements are satisfied.

Solution time is the total elapsed time, not counting the instruction period and practice problems, for the design solution. Solution time, as the dependent variable, obtains a multiple regression coefficient of $R^2 = .23$, $F\ (6, 39) = 1.95$, $p < .1$. Instability predicts almost half of this variance by itself, $t\ (45) = 2.98$, $p < .005$. Instability (as defined below) is a measure of how much the subject changed aspects of the library schedule the course of arriving at the final design. This result indicates, not-too-surprisingly, that the more subjects change their minds about their designs the longer they take to complete the problem.

Clustering ratio is ratio of the mean distance in the matrix representation of the final solution between pairs of procedures within a common group (Figure 2) and the mean distance between pairs of procedures not within a common group. (The distance metric used is the "city-block" metric.) A clustering ratio of 2.0 would mean that the mean distance between procedures in a common group is twice as great as the mean distance between procedures in different groups. A clustering ratio of .5 would mean that the mean distance between procedures in the same group was half as great as the mean distance between procedures in different groups. A clustering ratio of 1 indicates that mean distances are independent of "groups".

As far as we can tell, clustering ratio and performance are logically independent. That is, a higher or lower clustering ratio does not necessarily entail a higher or lower performance score. We have been able to construct solutions for the library scheduling problem which obtain performance scores of 24 and clustering ratios ranging from less than 1.0 to greater than 1.0. However, the clustering ratios actually obtained in the experiment tended to be smaller than 1.0, indicating that the schedules subjects design do reflect the structure of the problem description: library procedures that are related by more functional requirements tend to be located near to each other in the matrix, $t\ (45) = 10.95$, $p < .001$. The 95% confidence interval for the clustering ratio is $.58 < x < .71$. Recall that the ES subjects were explicitly told that the 12 procedures formed four groups, thus the fact that ES subjects obtain clustering ratios less than 1.0 shows only that the structure of the solution can be manipulated by direct instruction. *It would be more interesting if structure inherent, but not explicit, in the* problem (i.e., more functional requirements relating procedures in the same group than relating procedures in different groups) could also affect the structure of the designed schedule.

To assess this, we eliminated the ES subjects from the analysis. We still find that clustering ratios (for IS, NS, and SIM conditions) are smaller than 1.0, $t\ (33) = 9.55$, $p <$

.001. (The 95% confidence interval for clustering ratios in this case is .63 < x .76.) It is important to note, however, that subjects do not perfectly conform the structure of their designed schedules to the structure of the problem description. The expected value for clustering ratios in this experiment, assuming that they perfectly mimic the ratio of functional requirements defined in the problem, within groups versus between groups, is .167. However, the obtained clustering ratios are significantly different from this value, t (45) = 14.88, p < .001.

Clustering, as the dependent variate in a multiple regression analysis, obtains a coeficient of R^2 = .48, F (6, 39) = 5.91, p <.001. However, the only predictor that obtains a significant partial correlation with cluster is performance, t (45) = 4.18, p < .001. The explicit structure factor obtains a nearly significant partial correlation. A multiple regression with only the two predictors of performance and explicit structure reveals that explicit structure does predict clustering. This multiple regression obtains R^2 = .43, F (2, 43) = 15.96, p < .001. Performance and explicit structure both obtain significant partial correlations, t (45) = 4.82, p < .001, and t (45) = 2.58, p < .02, respectively.

The fourth measure of performance was instability. Instability is a measure of how much subjects in condition ES, IS, and NS changed their intermediate solutions. (Subjects in condition SIM, of course, do not produce a sequence of solutions and thus instability is not defined for them.) Recall that the procedure of the experiment requires subjects in the IS and NS conditions to produce a sequence of 7 solutions; in the ES condition, they produce 8 solutions. By the time the subject completes the first three of these partial solutions (the first four in ES), each of the 12 library procedures has appeared in at least one functional requirement. Thus, the subject has some basis for scheduling the entire set of 12 procedures somewhere in his schedule.

Of course, the functional requirements presented on the last few pages of the booklet may encourage subjects to alter their final schedules. Instability is a measure of how much subjects changed their schedules between the fourth to last and third to last, and between the third to last and second to last pages of the experimental booklet. (The subject receives no information on the last page of the booklet, except that it is the last page of the booklet.) We simply summed the total distance, using the city-block metric, that the subject moved each of the 12 procedures between succeeding pages. This total was the score for instability. It is also clear from the table that instability is greater than zero, people do change their solutions in the later stages of the problem. Instability is significantly different from zero, t (45) = 7.11, p < .001. The 95% confidence interval for instability is 12.49 < x < 22.51.

A fourth multiple regression was performed for the dependent variable of instability. (Because "instability" is not defined for the simultaneous condition, there are only five, instead of six, independent variables, or predictors, in this analysis. Also, only the 34 subjects in the three non-simultaneous conditions are included in the analysis.) A multiple regression coefficient of R^2 = .51, F (5, 28) = 5.82, p < .001, is obtained. Two predictors obtain significant partial correlations, solution time and explicit structure, t (33) = 3.14, p < .005, and t (33) = 2.67, p < .02, respectively. Performance is nearly significant, and when a multiple regression is performed for just the three predictors solution time, explicit structure, and performance, all of the partial correlations become significant. For these three factors, the multiple regression coefficient is R^2 = .49, F (3, 30) = 9.49, p < .001: For solution time, t (33) = 3.38, p < .005; for explicit structure, t (33) = 3.20, p < .005; and for performance, t (33) = 2.88, p < .01.

To summarize, clustering and performance are very good predictors for each other. Increased clustering correlates with better performance scores. This indicates that when the subject exploits the logical structure of the problem in his solution (clustering), he is able to

design a schedule that satisfies more requirements. Instability and solution time are also good predictors of each other. Increased instability correlates with increased solution time. When the structure of the solution fails to converge ballistically on a final schedule, the subject must change assignments late in the sequence of partial solutions, and the total solution time increases.

Explicit presentation (ES condition) correlates with both clustering and instability: Subjects assigned to the explicit structure condition tended to cluster more than subjects in the other conditions, and to change their solutions less in the later stages of the design problem. Thus, presentation apparently can influence the organization of design problem solving. This, however, is the only significant main effect of presentation condition that obtains, and in no case, as noted above, do we find that presentation condition predicts performance or solution time variables in this experimental situation.

Finally, instability correlates negatively with performance indicating that poorer final designs tend to be designs that are changed more in later stages of the problem. Thus, we have measured a main effect of the way subjects structure their problem solving activity in our design problem: Subjects who change their solutions more in later stages tend to have longer overall solution times and poorer solutions, subjects who cluster more have better solutions. Although our presentation manipulation does not yield a main effect vis-a-vis performance and solution time measures, there are some main effects vis-a-vis the "style" of solution elicited by at least one of our presentation conditions (i.e., the explicit structure condition with respect to instability and clustering).

We did not find that presentation condition (ES, IS, NS, SIM) significantly determines performance or solution time. To really make the case for the presentation variable, we would have had to demonstrate that presenting functional requirements in a jumbled sequence of partial presentations (NS) impoverishes design performance in some way, but this did not turn out to be the case. As noted above, ES does significantly predict instability and clustering, but the other presentation conditions are non-significant predictors.

The results of the experiment do, however, affirm the thesis that the structure of problem solution is predictably related to problem structure. Clustering, a measure of the extent to which a solution reflects the structure of the problem, predicts performance very significantly. There is also an interesting second order asymmetry with regard to clustering, which in fact provides some evidence that certain of our presentation manipulations were effective. For the NS condition, there is a negative simple correlation between instability and clustering, $r = -.61$, $z = 2.01$, $p < .05$. This indicates that increased instability accompanies increased clustering (smaller clustering ratios). However, in the ES and IS conditions the obverse is true. In these conditions, the simple correlation between instability and clustering is positive -- increased instability is associated with decreased clustering (larger ratios), $r = +.73$, $z = 3.11$, $p < .001$.

The NS presentation does not provide the subject with cues to the problem structure, at least not to the extent that the ES and IS presentations do. Accordingly, NS subjects must change their schedules around to conform them to the structure of the problem. ES and IS subjects, on the other hand, must not change their schedules around, or else the schedules will fail to conform to the problem's structure.

Summary

The present experiment furthers the investigation of design problem solving initiated in Carroll et al. (1978). We believe that we now have a fairly good grasp of this design problem scenario. In the present experiment, we did not have to exclude a single subject for failing to

understand the problem statement (in contrast with Carroll et al., 1978), even though in many respects the problem we used was more difficult than the one we employed in the earlier study. The problem scenario could be used by other investigators interested in extending conventional problem solving studies to design type problems.

We were able to develop two new measures of solution structure, cluster and stability, and to systematically relate these to performance and solution time. The former assesses the degree to which a given solution reflects the problem structure as defined by the distribution of problem's functional requirements. The latter assess the degree to which subjects alter their solutions in very late stages of their designing activity. We found that cluster is highly correlated with performance score, and that stability is inversely correlated with solution time. Further research will be required, however, to elaborate these very striking relations between problem structure and solution structure.

We failed to measure clear-cut effects of our problem statement variable, that being sequence of presentation. None of our four presentation conditions was markedly different from any of the others. However, we did find some suggestive results. It seems that making the problem structure explicitly apparent in the problem statement (i.e., sequence of presentaiton) can have the effect of encouraging stability and clustering in obtained solutions. Thus, while we do not presently have evidence that our problem statement manipulation affects the success or speed of solution, we do find that it can affect the character of the solution structure.

REFERENCES

Brunswik, E. Perception and the representative design of psychological experiments. Berkeley: University of California Press, 1956.

Carroll, J.M., Thomas, J.C., & Malhotra, A. Presentation and representation in design problem solving. IBM Research Report, RC 6975, 1978.

Cohen, J. Multiple regression as a general data-analytic system. Psychological Bulletin, 1968, 70, 426-443.

Reitman, W. Cognition and thought. New York: Wiley. 1965.

Simon, H.A. The structure of ill-structured problems. Artificial Intelligence, 1973, 4, 181-201.

Simon, H.A., & Hayes, J.R. The understanding process: problem isomorphs. Cognitive Psychology, 1976, 8, 165-190.

APPENDIX

The text of the problem description for the explicit structure (ES) presentation condition appears as the final pages of this report.

EXPERIMENT IN DESIGN PROBLEM SOLVING

Introduction: Library Procedures

Although most of us use libraries, we usually don't stop to think about the organization that keeps the library running smoothly. There are many separate procedures that need to be carried out in order for a library to function effectively and efficiently: new books must be cataloged and shelved, books returned must be checked off and reshelved, old books no longer in circulation must be recataloged and stored in archives, magazine racks must be kept up to date, etc. These different procedures are related in various ways. There are three sorts of relations between procedures that you will be dealing with today: facilitation, priority, and resource sharing. Facilitation refers to the fact that certain procedures act as preconditions for other procedures, and therefore ought to be scheduled before those procedures. Priority refers to the fact that certain procedures are more important than others, and therefore should receive more attention. Resource sharing refers to the fact that certain resources employ the same resources and therefore can be more efficiently taken care of together than they can be separately. We will now explain in more detail what these three relations are like.

Facilitation. Certain procedures ought to be sequentially organized. Thus, new books should not be shelved before they have been cataloged, otherwise people who use the library will not be able to locate the new books in the catalogs. Moreover, cataloging a book informs the library staff members of where the book should be properly shelved. Cataloging, in this sense, facilitates shelving, and therefore ought to be carried out before shelving. Conversely, shelving is facilitated by cataloging and accordingly ought to be scheduled after cataloging.

Priority. Another way library procedures are related is in terms of their "priority", certain procedures seem to be more important that others: Shelving new books seems to be more important than moving out-of-date books into archive storage. When one procedure has higher priority than another, it is more important for that procedure to be taken care of. In organizing a library, one would want to make sure that higher priority procedures received more attention than lower priority procedures. Note that the relation of priority is independent of facilitation (and conversely): A procedure can facilitate another procedure and have either higher or lower priority than that other procedure. For example, if we assume that cataloging facilitates shelving, we can assign cataloging either higher or lower priority than shelving -- the priority of the two procedures does not influence their facilitation relation. Similarly, if we know that shelving new books has higher priority than moving old books to storage, we know nothing about whether and how the two procedures facilitate each other. It could be that shelving new books actually facilitates removing old books, or it could be that removing old books facilitates shelving new books (this seems more reasonable). The point is that we cannot tell anything about priority from facilitation and vice versa.

Resources. Finally, library procedures are related in terms of the resources they employ. For example, certain sets of procedures can be taken care of by the same employees or by the same machines, and therefore can be scheduled together. Other procedures must be taken care of by different employees or require different machines, etc., and therefore should not be scheduled together. When library procedures require the same resources, they can be scheduled for the same time. However, when two procedures require different resources they should not be scheduled for the same time. Thus, a greater amount of work can be taken care of more efficiently. Note that resources are independent of priority, and vice versa. If two procedures use the same resources, we do not know which one has higher priority. On the other hand, just knowing which procedure has higher priority tells us nothing about whether the two processes employ the same resources or not. Resources are not independent of facilitation, however. If two procedures employ the same resources, they cannot facilitate each other because they will be scheduled for the same time. Conversely, if one procedure facilitates another procedure, and therefore is scheduled before the other procedure, the two procedures clearly cannot be scheduled together -- and hence cannot employ the same resources. If two procedures employ different resources, then, of course, one may facilitate the other. For a library to be a good library, these various different library procedures must be sensibly organized to maximize efficiency, minimize cost, and in general to keep library users happy.

Designing a Library Schedule.

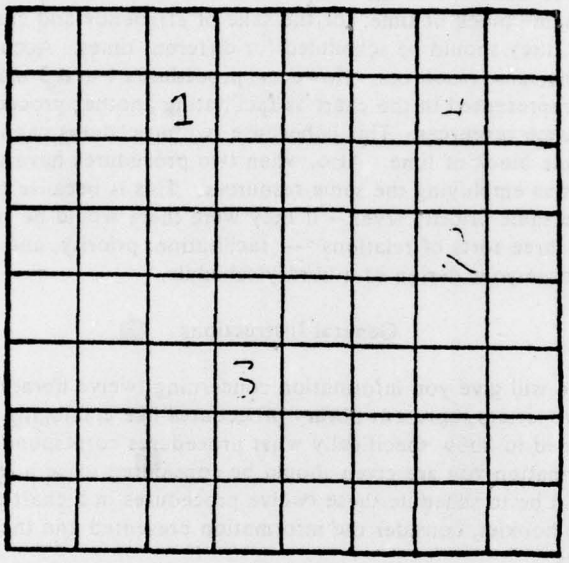
This is an experiment in design problem solving. During the experiment, you will be designing a schedule for a set of hypothetical library procedures. We will tell you various facts about each procedure, and you will then try to integrate these facts and design the best possible schedule for the set of procedures. The schedule for the library system will be represented in a chart like the one below.

<---(earlier)--------- TIME ---------(later)--->

(higher)

PRIORITY

(lower)



To represent a schedule for a set of procedures, you mark each procedure in a square of the chart (only one procedure can be marked in any one square). This chart is a sort of time line. The dimension of "time" goes from left to right --squares further to the left are "earlier" than squares to the right. Procedures marked in squares in the same column of the chart (that is, directly above or below one another) are all scheduled together for the same block of time.

Representing Facilitation in the Schedule. If you want to schedule a certain procedure before another procedure, the earlier procedure should be marked in the chart somewhere to the left of the later procedure. As you can see in the example chart, procedure "1" is scheduled to be earlier than procedure "2". Of course, procedures can also be scheduled to be carried out during the same period of time. In the example, procedures 2 and 4 are scheduled together (they are both scheduled after procedure 1). As you design your library schedule, if you are told that one procedure "facilitates" another procedure, you should try to schedule the facilitating procedure before the procedure it facilitates. (According to the example chart, procedure 1 facilitates procedures 2, 3, and 4; and procedure 3 facilitates procedures 3 and 4.) It doesn't really matter whether the facilitating procedure is scheduled immediately before the procedure it facilitates or long before that procedure, as long as it is scheduled somewhere before that procedure -- procedure 1 facilitates procedures 3 and 4 equally even though it is scheduled directly before procedure 3 but remotely before procedure 4.

Representing Priority in the Schedule. The dimension of "priority" goes from top to bottom in the chart -- procedures marked higher in the chart have higher priority. In designing a schedule, it is important to show which procedures are most important and which are least important. Then, if for some reason, not all of the scheduled procedures can be carried out, it will be the more important ones that will be given priority over the least important ones. In the example, procedures 1 and 4 both have higher priority than procedures 2 and 3. Procedure 2 has higher priority than procedure 3, although it has lower priority than procedures 1 and 4. Procedures 1 and 4 have equal priority. If you had been told, for example, that procedure 1 has higher priority than procedure 3, you would try to schedule procedure 1 higher in the chart than procedure 3. When you want to represent higher priority it is not important to

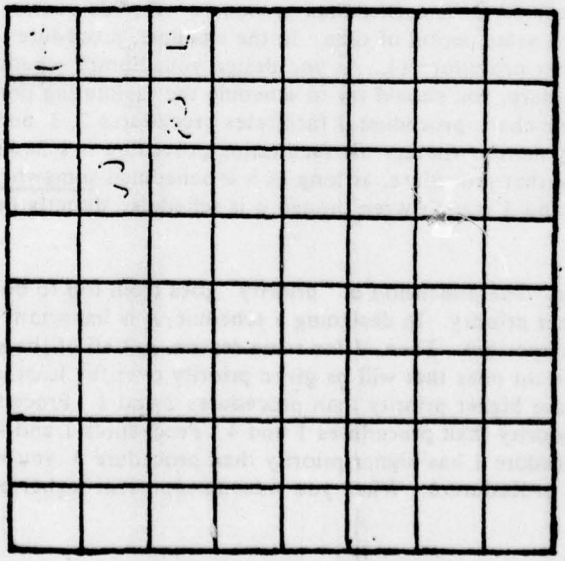
place the higher priority procedure directly above the lower priority procedure -- procedure 1 and procedure 3 are not directly aligned, but procedure 1 has higher priority than procedure 3. Note that you represent priority independently of facilitation. A procedure can facilitate another procedure whether it is higher or lower in priority than that other procedure. And a procedure can be higher (or lower)in priority than another procedure whether it facilitates that procedure or is facilitated by that procedure.

Representing Resource Sharing in the Schedule. The third way in which procedures can be related is by the resources they employ. When two procedures make use of the same resources, the same employees, the same machines, etc., they should be scheduled for the same block of time, for the sake of efficiency and convenience. If procedures employ different sets of resources, they should be scheduled for different times. According to the example chart, procedures 2 and 4 make use of the same resources. However, procedures 1 and 3 make use of different resources. Note that when one procedure is represented in the chart as facilitating another procedure, the two procedures cannot be represented as employing the same resources. This is because two procedures cannot be scheduled one before the other and be scheduled for the same block of time. Also, when two procedures have the same priority level, they cannot be represented in the chart as employing the same resources. This is because two procedures cannot be scheduled for the same time at the same priority level -- if they were there would be two procedures marked in a single square of the chart. These three sorts of relations --- facilitation, priority, and resources ---are the types of information upon which you will base your design of a library schedule.

General Instructions

On each of the next few pages, we will give you information concerning twelve library procedures: A, B, C, D, E, F, G, H, I, J, K, and L. These twelve letters represent library procedures like cataloging books, organizing the magazine racks, etc. However, you don't need to know specifically what procedures correspond to what letters in order to work this problem. Each piece of information you are given should be considered to be a requirement on the schedule you are going to design. Your goal will be to schedule these twelve procedures in a chart like the example chart. When you turn to each new page of this booklet, consider the information presented and then try to design the best possible schedule for the twelve procedures.

Please consider all of the information you receive to be equal. It is just as important, for example, to schedule procedures that use different resources for different blocks of time as it is to schedule a procedure that faciltates another procedure sometime before that procedure. Each piece of information you receive should weigh equally in the design of your schedule. Also, when you have a choice, try to schedule procedures as early (that is, as far towards the left-hand side of the chart) as possible; and assign procedures the highest priority possible (that is, place them nearest to the top of the chart). Hence, the example chart discussed earlier should really be compacted, as indicated below.



Sometimes you will find that you simply cannot design a schedule that satisfies all of the facts you know about the twelve library procedures. In that case, try to do the best you can -- if you cannot satisfy a given requirement, try to get as close as you can. It's always better to miss by a little than to completely give up on any particular requirement. For example, if you are told that procedure 1 facilitates procedure 2 but you find that, for one reason or another, you cannot organize your schedule so that it satisfies this requirement, it would be better to have procedures 1 and 2 scheduled together (at the same time) than to have procedure 2 actually before procedure 1 -- thereby outrightly contradicting the fact that 1 facilitates 2. Always try to obtain the best possible overall schedule for the procedures.

Sometimes you will simply not know what sort of relation exists between two procedures. In that case, just make the most convenient assumption. For example, suppose you were told that procedure 1 employs different resources than procedure 2, and that procedure 2 employs different resources than procedure 3. From these facts, you would not know whether procedure 1 employs the same resources as procedure 3, or not. In such a case, just make the most convenient assumption: you would be free to assume that procedures 1 and 3 employ the same resources, or that they employ different resources.

The problem should be thought of as "cumulative". That is, each time you turn to new page and begin to design a schedule keep in mind all of the facts you were given on all of the previous pages of the booklet. Thus, on each new page you will be dealing with more information. Sometimes you will be able to just add to a schedule you designed earlier in the booklet, and thereby short-cut your work later in the booklet. However, information you receive on a later page may also sometimes force you to reformulate the problem and even to discard some of your earlier work.

We are interested in your intermediate solutions -- even the ones you later discard -- as well as in the final schedule you settle on. As you progress through this booklet, do not change anything on pages previous to the page you are working on, we are interested in your intermediate solutions -- do not change your earlier work. When you finish with the final page of the booklet and design your final schedule for the library procedures, signal the experimenter. (Feel free to make notes in the margins of the pages of the booklet.)

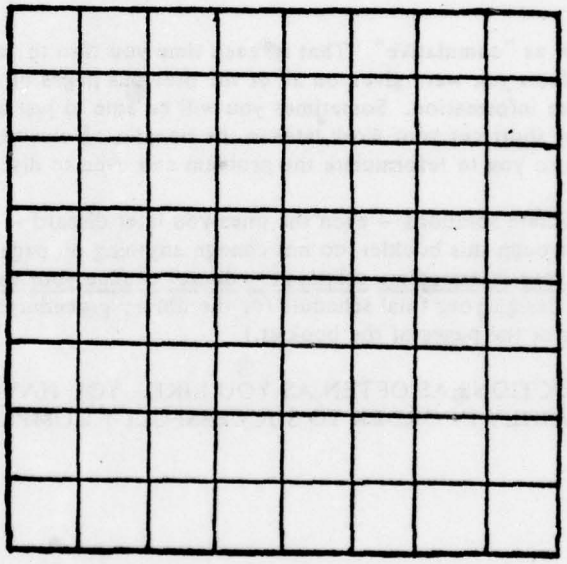
PLEASE READ THESE INSTRUCTIONS AS OFTEN AS YOU LIKE. YOU HAVE TO UNDERSTAND THESE FIRST FOUR PAGES THOROUGHLY IN ORDER TO SUCCESSFULLY COMPLETE THE PROBLEM.

Practice Problem

To be sure that you understand the various ways that library procedures can be related to one another, try to work this practice problem. In the practice problem, there are only four procedures. We know the following facts about them:

1. Procedure 1 facilitates procedure 4.
2. Procedure 2 has higher priority than procedure 1.
3. Procedure 3 employs the same resources as procedure 2.
4. Procedure 3 is facilitated by procedure 4.

Indicate in the chart a possible schedule for these library procedures.



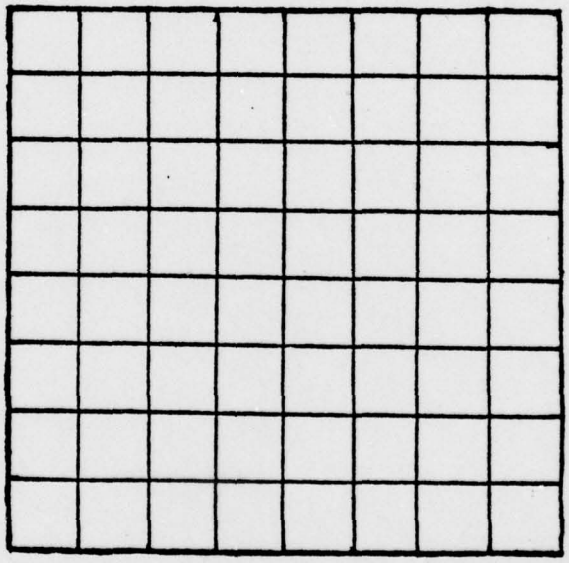
SIGNAL THE EXPERIMENTER WHEN YOU ARE FINISHED WITH THE PRACTICE PROBLEM. DO NOT TURN THE PAGE UNTIL YOU ARE INSTRUCTED TO DO SO. PLEASE ASK ANY QUESTIONS THAT OCCUR TO YOU. REREAD THE FIRST FOUR PAGES OF INSTRUCTIONS NOW AND AT ANY TIME DURING THE EXPERIMENT.

Practice Problem

This second practice problem provides another chance for you to check out your understanding of the problem. If you did less than perfectly on the first practice problem, you should try to solve this problem. In this practice problem, there are four procedures; they are related in the following ways.

1. Procedure 1 has lower priority than procedure 2.
2. Procedure 2 employs different resources than procedure 3.
3. Procedure 4 facilitates procedure 3.
4. Procedure 1 employs the same resources as procedure 3.

Indicate in the chart a possible schedule for these four library procedures.

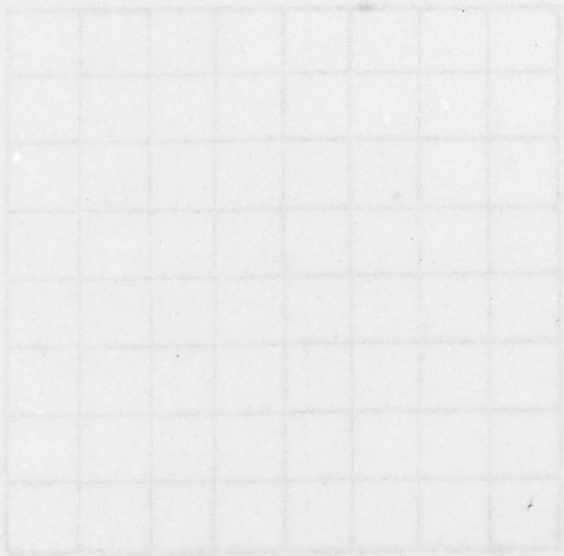


SIGNAL THE EXPERIMENTER WHEN YOU ARE FINISHED WITH THE PRACTICE PROBLEM. DO NOT TURN THE PAGE UNTIL YOU ARE INSTRUCTED TO DO SO. PLEASE ASK ANY QUESTIONS THAT OCCUR TO YOU, REREAD THE FIRST FOUR PAGES OF INSTRUCTIONS NOW AND AT ANY TIME DURING THE EXPERIMENT.

STOP

DO NOT GO ON UNTIL DIRECTED TO DO SO BY EXPERIMENTER.

THE LIBRARY SCHEDULE PROBLEM BEGINS ON THE NEXT PAGE.



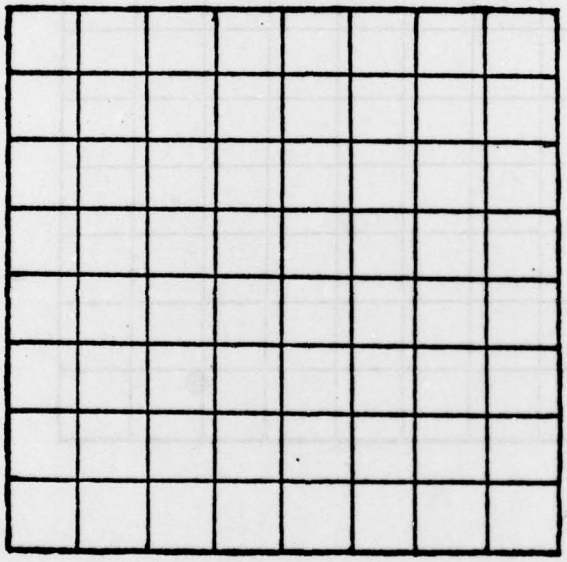
The twelve library procedures are organized into three groups of four procedures each. Each group of procedures are taken care of by a different group of library staff members.

Group I includes procedures A, B, C, and D.
Group II includes procedures E, F, G, and H.
Group III includes procedures I, J, K, and L.

There are several general facts about the ways in which these groups of procedures interact.

1. In general, Group I procedures are facilitated by Group II procedures.
2. In general, Group II procedures require the same resources as Group III procedures.
3. In general, Group III procedures have higher priority than Group I procedures.

Indicate in the chart a schedule for the three groups of library procedures. Keep in mind that these are only generally true facts. Thus, from number 2 above you should not conclude that all eight of the procedures in groups II and III are to be scheduled in the same single block of time. Rather, number 2 means that in general group II procedures can be scheduled at the same time as group III procedures. (Recall that each group consists of four procedures, therfore in the chart you should alot four squares for the scheduling of each group of procedures.)



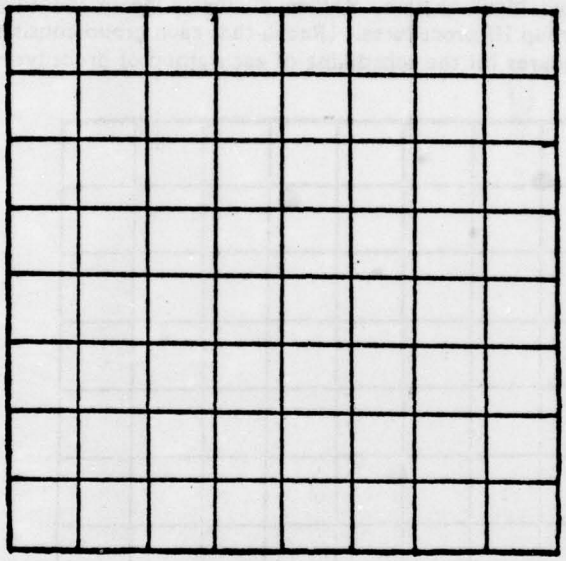
Do you have any questions or comments on the design problem thus far? Are there any facts in particular that you would like to know at this point?

DO NOT TURN THE PAGE UNTIL YOU ARE COMPLETELY FINISHED WITH THIS STAGE OF THE PROBLEM. YOU MAY LOOK AT EARLIER PAGES OF THE BOOKLET BUT NOT SUBSEQUENT PAGES. AFTER YOU TURN THE PAGE AND BEGIN WORK ON THE NEXT STAGE OF THE PROBLEM, YOU MAY NOT ADD TO OR DELETE FROM ANY PREVIOUS PAGES.

On this page, you will learn more about the procedures in Group I.

1. Procedure B employs the same resources as procedure C.
2. Procedure A is higher in priority than procedure B.
3. Procedure C is facilitated by procedure D.
4. Procedure D is lower in priority than procedure A.

Indicate in the chart a schedule for the library procedures.



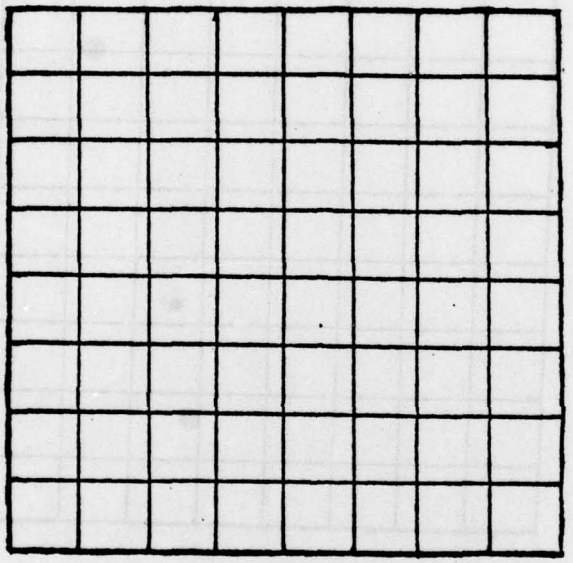
Do you have any questions or comments on the design problem thus far? Are there any facts in particular that you would like to know at this point?

DO NOT TURN THE PAGE UNTIL YOU ARE COMPLETELY FINISHED WITH THIS STAGE OF THE PROBLEM. YOU MAY LOOK AT EARLIER PAGES OF THE BOOKLET BUT NOT AT SUBSEQUENT PAGES. AFTER YOU TURN THE PAGE AND BEGIN TO WORK ON THE NEXT STAGE OF THE PROBLEM, YOU MAY NOT ADD TO OR DELETE FROM ANY PREVIOUS PAGES.

On this page, you will learn more about the procedures in Group II.

1. Procedure H is facilitated by procedure F.
2. Procedure G facilitates procedure E.
3. Procedure E employs different resources than procedure H.
4. Procedure F is lower in priority than procedure G.

Indicate in the chart a schedule for the library procedures (keeping in mind all previously presented information).



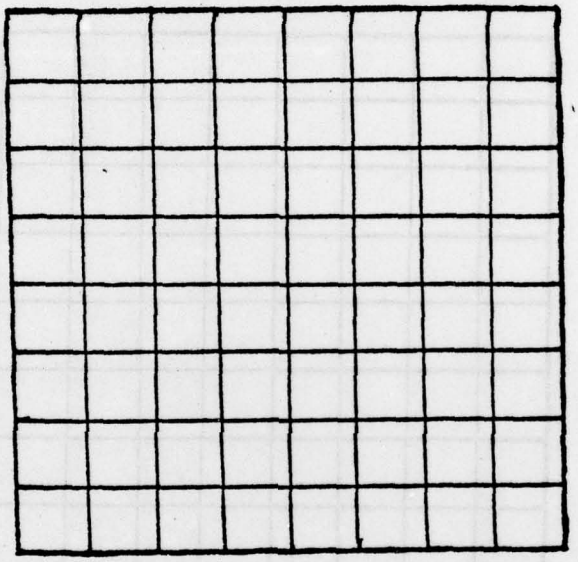
Do you have any questions or comments on the design problem thus far? Are there any facts in particular that you would like to know at this point?

DO NOT TURN THE PAGE UNTIL YOU ARE COMPLETELY FINISHED WITH THIS STAGE OF THE PROBLEM. YOU MAY LOOK AT EARLIER PAGES OF THE BOOKLET BUT NOT AT SUBSEQUENT PAGES. AFTER YOU TURN THE PAGE AND BEGIN TO WORK ON THE NEXT STAGE OF THE PROBLEM, YOU MAY NOT ADD TO OR DELETE FROM ANY PREVIOUS PAGES.

On this page, you will learn more about the procedures in Group III.

1. Procedure K facilitates procedure L.
2. Procedure I is higher in priority than procedure J.
3. Procedure J employs the same resources as procedure K.
4. Procedure L employs different resources than procedure I.

Indicate in the chart a schedule for the library procedures (keeping in mind all previously presented information).



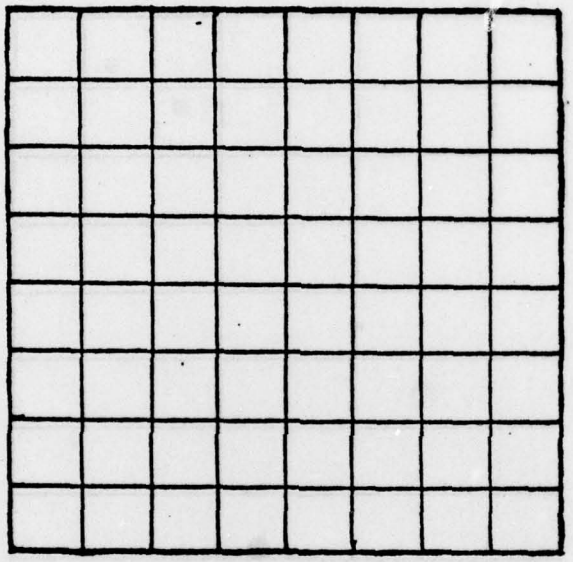
Do you have any questions or comments on the design problem thus far? Are there any facts in particular that you would like to know at this point?

DO NOT TURN THIS PAGE UNTIL YOU ARE COMPLETELY FINISHED WITH THIS STAGE OF THE DESIGN PROBLEM. YOU MAY LOOK AT EARLIER PAGES OF THE BOOKLET BUT NOT AT SUBSEQUENT PAGES. AFTER YOU TURN THE PAGE AND BEGIN TO WORK ON THE NEXT STAGE OF THE PROBLEM, YOU MAY NOT ADD TO OR DELETE FROM ANY PREVIOUS PAGES.

On this page, you will learn more about the twelve library procedures.

1. Procedure D is facilitated by procedure G.
2. Procedure A is lower in priority than procedure J.
3. Procedure H employs the same resources as procedure L.
4. Procedure C employs different resources than procedure F.

Indicate in the chart a schedule for the library procedures (keeping in mind all previously presented information).



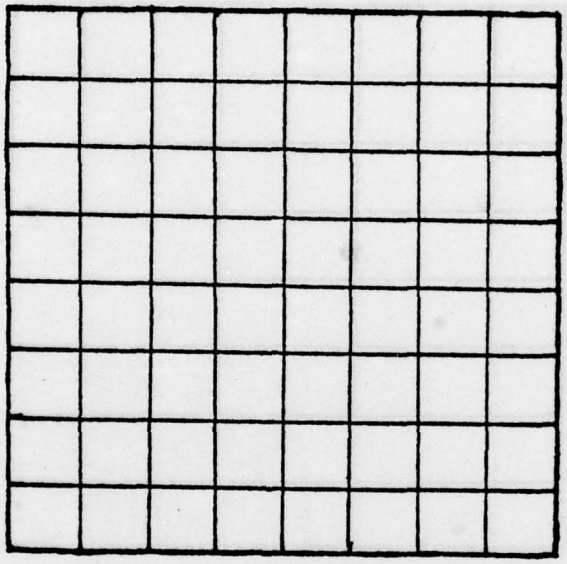
Do you have any questions or comments on the design problem thus far? Are there any facts in particular that you would like to know at this point?

DO NOT TURN THIS PAGE UNTIL YOU ARE COMPLETELY FINISHED WITH THIS STAGE OF THE PROBLEM. YOU MAY LOOK AT EARLIER PAGES OF THE BOOKLET BUT NOT AT SUBSEQUENT PAGES. AFTER YOU TURN THE PAGE AND BEGIN TO WORK ON THE NEXT STAGE OF THE PROBLEM, YOU MAY NOT ADD TO OR DELETE FROM ANY PREVIOUS PAGES.

On this page, you will learn more about the twelve library procedures.

1. Procedure G facilitates procedure B.
2. Procedure F employs the same resources as procedure I.
3. Procedure E is lower in priority than procedure K.
4. Procedure J is higher in priority than procedure C.

Indicate in the chart a schedule for the library procedures (keeping in mind all previously presented information).



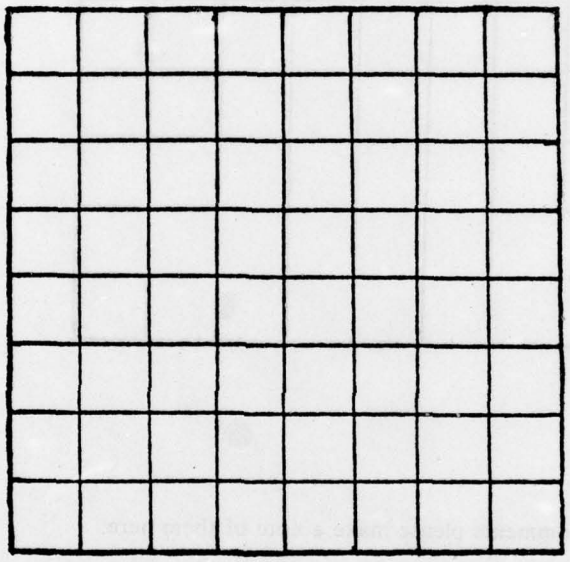
Do you have any questions or comments on the design problem thus far? Are there any facts in particular that you would like to know at this point?

DO NOT TURN THIS PAGE UNTIL YOU ARE COMPLETELY FINISHED WITH THIS STAGE OF THE PROBLEM. YOU MAY LOOK AT EARLIER PAGES OF THE BOOKLET BUT NOT AT SUBSEQUENT PAGES. AFTER YOU TURN THE PAGE AND BEGIN TO WORK ON THE NEXT STAGE OF THE PROBLEM, YOU MAY NOT ADD TO OR DELETE FROM ANY PREVIOUS PAGES.

On this page, you will learn more about the twelve library procedures.

1. Procedure B is facilitated by procedure E.
2. Procedure L employs different resources than procedure D.
3. Procedure I facilitates procedure H.
4. Procedure K has higher priority than procedure A.

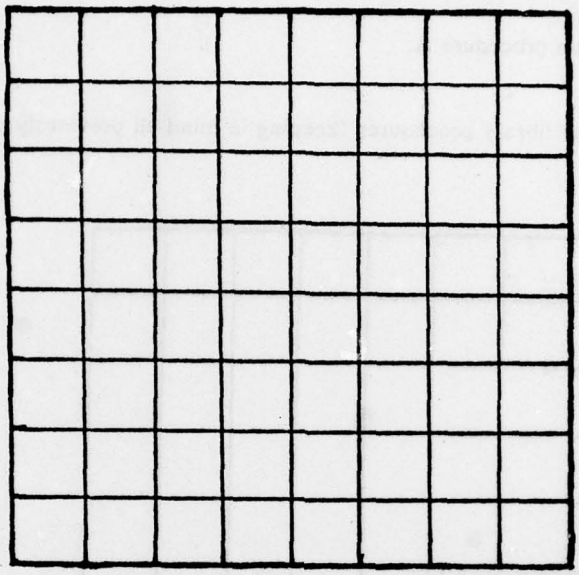
Indicate in the chart a schedule for the library procedures (keeping in mind all previously presented information).



Do you have any questions or comments on the design problem thus far? Are there any facts in particular that you would like to know at this point?

DO NOT TURN THIS PAGE UNTIL YOU ARE COMPLETELY FINISHED WITH THIS STAGE OF THE PROBLEM. YOU MAY LOOK AT EARLIER PAGES OF THE BOOKLET BUT NOT AT SUBSEQUENT PAGES. AFTER YOU TURN THE PAGE AND BEGIN TO WORK ON THE NEXT STAGE OF THE PROBLEM. YOU MAY NOT ADD TO OR DELETE FROM ANY PREVIOUS PAGES.

You now have all of the information relating the twelve library procedures. Please fill in the chart to indicate your final schedule solution to the design problem. (Make sure that your schedule takes into account all of the information you have been presented with.)



If you have any final questions or comments please make a note of them here.

PLEASE SIGNAL THE EXPERIMENTER WHEN FINISHED WITH THIS PAGE.

OFFICE OF NAVAL RESEARCH, CODE 455
TECHNICAL REPORTS DISTRIBUTION LIST

Director, Engineering Psychology
Programs, Code 455
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217 (5 cys)

Defense Documentation Center
Cameron Station
Alexandria, VA 22314 (12 cys)

Dr. Robert Young
Director, Cybernetics Technology Office
Advanced Research Projects Agency
1400 Wilson Blvd.
Arlington, VA 22209

Col. Henry L. Taylor, USAF
OAD (E&LS) ODDR&E
Pentagon, Room 3D129
Washington, D.C. 20301

Office of Naval Research
International Programs
Code 102IP
800 North Quincy Street
Arlington, VA 22217 (6 cys)

Director, Information Systems
Program, Code 437
Office of Naval Research
800 North Quincy Street
Arlington, VA 22217

Commanding Officer
ONR Branch Office
ATTN: Dr. J. Lester
495 Summer Street
Boston, MA 02210

Commanding Officer
ONR Branch Office
ATTN: Dr. Charles Davis
536 South Clark Street
Chicago, IL 60605

Commanding Officer
ONR Branch
ATTN: Dr. E. Gloye
1030 East Green Street
Pasadena, CA 91106

Dr. B. McDonald
Office of Naval Research
Scientific Liaison Group
American Embassy, Room A-407
APO San Francisco 96503

Director, Naval Research
Laboratory
Technical Information Division
Code 2627
Washington, D.C. 20375 (6 cys)

Office of the Chief of Naval
Operations, OP987P10
Personnel Logistics Plans
Department of the Navy
Washington, D.C. 20350

CDR Paul Nelson
Naval Medical R&D Command
Code 44
Naval Medical Center
Bethesda, MD 20014

Director
Behavioral Sciences Department
Naval Medical Research Institute
Bethesda, MD 20014

Dr. George Moeller
Human Factors Engineering Branch
Submarine Medical Research
Laboratory
Naval Submarine Base
Groton, CT 06340

Bureau of Naval Personnel
Special Assistant for Research
Liaison
PERS-OR
Washington, D.C. 20370

Navy Personnel Research and
Development Center
Management Support Department
Code 210
San Diego, CA 92152

Naval Training Equipment Center
ATTN: Technical Library
Orlando, FL 32813

Human Factors Department
Code N215
Naval Training Equipment Center
Orlando, FL 32813

Dr. Alfred F. Smode
Training Analysis and
Evaluation Group
Naval Training Equipment Center
Code N-OOT
Orlando, FL 32813

Dr. Gary Poock
Operations Research Department
Naval Postgraduate School
Monterey, CA 93940

Dr. A. L. Slafkosky
Scientific Advisor
Commandant of the Marine Corps
Code RD-1
Washington, D.C. 20380

Mr. J. Barber
Headquarters, Department of the
Army, DAPE-PBR
Washington, D.C. 20546

Dr. Joseph Zeidner
Director, Organization and
Systems Research Laboratory
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. Edgar M. Johnson
Organization and Systems
Research Laboratory
U.S. Army Research Lab
5001 Eisenhower Avenue
Alexandria, VA 22333

Technical Director
U.S. Army Human Engineering Labs
Aberdeen Proving Ground
Aberdeen, MD 21005

U.S. Air Force Office of Scientific
Research
Life Sciences Directorate, NL
Bolling Air Force Base
Washington, D.C. 20332

Dr. Donald A. Topmiller
Chief, Systems Engineering Branch
Human Engineering Division
USAF AMRL/HES
Wright-Patterson AFB, OH 45433

Lt. Col. Joseph A. Birt
Human Engineering Division
Aerospace Medical Research
Laboratory
Wright Patterson AFB, OH 45433

Air University Library
Maxwell Air Force Base, AL 36112

Dr. Alphonse Chapanis
The Johns Hopkins University
Department of Psychology
Charles & 34th Streets
Baltimore, MD 21218

Dr. Arthur I. Siegel
Applied Psychological
Services, Inc.
404 East Lancaster Street
Wayne, PA 19087

Dr. Gerson Weltman
Perceptronics, Inc
6271 Variel Avenue
Woodland Hills, CA 91364

Dr. J. A, Swets
Bolt, Beranek and Newman, Inc.
50 Moulton Street
Cambridge, MA 02138

Dr. H. Rudy Ramsey
Science Applications, Inc.
40 Denver Technological
Center West
7935 East Prentice Avenue
Englewood, Colorado 80110

Dr. Meredith Crawford
5606 Montgomery Street
Chevy Chase, MD 20015

Professor Douglas E. Hunter
Defense Intelligence School
Washington, D.C. 20374

Dr. James H. Howard
Catholic University
Department of Psychology
Washington, D.C. 20064

Dr. Jesse Orlansky
Institute for Defense Analyses
400 Army-Navy Drive
Arlington, VA 22202

Journal Supplement Abstract
Service
American Psychological
Association
1200 17th Street, N.W.
Washington, D.C. 20036 (3 cys)

Dr. William A. McClelland
Human Resources Research Office
300 N. Washington Street
Alexandria, VA 22314

Dr. Tom Love
General Electric Company
Information Systems Programs
1755 Jefferson Davis Highway
Arlington, VA 22202

Dr. David J. Getty
Bolt, Beranek & Newman
50 Moulton Street
Cambridge, MA 02139

Director, Human Factors Wing
Defence & Civil Institute of
Environmental Medicine
Post Office Box 2000
Downsville, Toronto, Ontario
CANADA

Dr. A. D. Baddeley
Director, Applied Psychology Unit
Medical Research Council
15 Chaucer Road
Cambridge, CB2 2EF
ENGLAND

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Aspects of Solution Structure in Design Problem Solving		5. TYPE OF REPORT & PERIOD COVERED Interim Technical Report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John M. Carroll John C. Thomas Lance A. Miller		8. CONTRACT OR GRANT NUMBER(s) N00014-72-C-0419
9. PERFORMING ORGANIZATION NAME AND ADDRESS International Business Machines T.J.Watson Research Center, P.O.Box 218 Yorktown Heights, N.Y. 10598		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR-197-020
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Code 455 Arlington, Virginia		12. REPORT DATE 13. NUMBER OF PAGES 24
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

ABSTRACT: Forty-eight subjects reiteratively designed a schedule for a set of abstract library procedures. Obtained solution schedules were measured in terms of (1) solution time, (2) satisfaction of functional design requirements, (3) stability of solution through the sequence of iterations, and (4) cluster, the degree to

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. (cont.)

which solutions reflected the inherent structure of the problem. It was found that the extent to which schedules were clustered was a significant predictor of satisfaction of functional design requirements, and that the stability of solutions was a significant predictor of solution time. Weak effects of problem statement on solution variables were also identified.